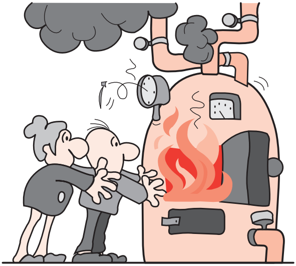
BEST PRACTICE • PROGRAMME •

ENERGY EFFICIENCY

• EVERYONE'S GUIDE TO •

saving energy with boilers



Contents

Note
This booklet is mainly concerned with boilers using fossil fuels, but it should be noted that there are also boilers, hot water systems and steam raising equipment that are electrically powered.

The basics

In simple terms, a boiler is a vessel for converting the heat produced by the combustion of a fuel into hot water or steam. Boilers come in all sorts of shapes and sizes, with different capabilities dependent upon whether you are just trying to heat a small office or raising steam to generate electricity for the National Grid.

Whatever size of boiler you have, its operational efficiency has an impact on your company's bottom line profit. The boiler is the place where the fossil fuel is converted to heat for use in the heating or domestic hot water system. A two or three per cent improvement in efficiency here can give profits a boost.

There have been many improvements in boiler design over recent years and this new technology will improve performance and efficiency. If your boiler plant is 20 or more years old it is time to start looking at options for your future heat generation strategy.

In a booklet this size we cannot cover all the different types of boiler available, so instead a few examples are given that can point you in the right direction.

Heating and hot water

Older boilers used for heating and hot water were of the cast iron sectional type. They were large compared to modern boilers, and therefore the radiated heat from the surface of the boiler was much higher, increasing losses. The boilers also had large passages for the hot gases to pass through which meant that heat transfer into the boiler water was not very efficient. Losses from this type of boiler can easily be 30% or more. Some of these boilers were designed to use coal or oil as a fuel and have subsequently been converted to run on natural gas. Dependent upon the design of the firing

chamber, some of these conversions decreased the efficiency and output capacity of the boiler.

Modern boilers are much more compact, well insulated and designed to provide high heat transfer rates. Boiler efficiency is therefore much improved, with typical losses ranging between 16% and 20%

Heat from the boiler is used directly in the heating system and is often also passed through a tube bundle within a storage vessel (called a calorifier) in order to generate domestic hot water (DHW).

Manufacturers can now offer boilers that generate the DHW inside the boiler. These are called combination boilers. Again these boilers provide savings from reducing the standing losses from the DHW calorifier.

Another development is the condensing boiler. This modern equipment has additional heat exchanger surfaces in the boiler which take more heat out of the flue gases before they enter the chimney. This provides further efficiencies, reducing overall losses to 5-10%.

However, condensing boilers are usually used with natural gas as the fuel. This is because the flue gases are condensed by the extra heat exchange surfaces and the water in the flue will combine with any sulphur present in the fuel to create sulphuric acid, which will eat into the chimney system. Different grades of oil contain sulphur of varying amounts, whereas natural gas contains none. Therefore if oil is to be used as the fuel for a condensing boiler, the heat exchanger must be of stainless steel to avoid corrosion.

In general, the combustion system will be a pressure jet burner or a series of atmospheric burner bars. The setting and control of these combustion systems requires skilled knowledge in order to obtain peak efficiencies.

Process heating

Where heat is being generated for process purposes it is usually required at higher temperatures and therefore steam or high-temperature hot water (HTHW) is used.

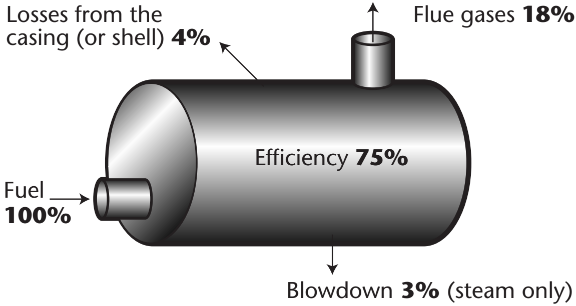
This type of boiler plant tends to be much larger and of a different design, usually either shell and tube or water tube package boilers. These boilers are designed as pressure vessels so that an elevated temperature can be achieved in the water or steam.

Combustion systems in these boilers will be either a series of pressure jet burners or a rotary cup burner.

These boilers are much more complex and require skilled attention to maintain peak efficiencies.

Where are the losses?

All boilers will have losses to a greater or lesser degree dependent upon the age and maintenance of the plant. The diagram below shows where the losses occur.



Where are the savings?

Savings are achieved by reducing the losses.

Improved heat transfer from the flame in the boiler to the water will reduce flue gas losses by reducing the temperature of the gases going up the chimney. There are two areas here that must be considered.

- **Flue gas side:** When a fuel is burnt, there is the possibility of creating soot if combustion conditions are not correct. (Put a spoon over a candle flame, and you will see soot appear because proper combustion is not occurring). Inside a boiler, that soot, if present, will insulate the heat of the flame away from the water. Some fuels are cleaner than others. Gas tends to be clean when compared to oil. The lighter the grade of oil the cleaner it tends to burn.

- **Water side:** Fouling of the water side surfaces is dependent upon the quality of the water in the boiler, for example hard water scales up easily (think of the element in your kettle). Water treatment chemicals can be used to minimise water side fouling. This is especially important in steam boilers. As the water evaporates to steam, the hardness impurities in the water are left behind and therefore gradually build up. This is why steam boilers have to be 'blown down' regularly to discharge this build-up of impurities. Large boiler plants are sometimes equipped with water treatment plants to remove the impurities before the water enters the boiler.

Improved combustion efficiency will reduce flue gas losses by ensuring that all the energy in the fuel is released without using too much excess air.

There is a delicate balance to be achieved between the amount of fuel and the air required to burn the fuel. The carbon and hydrogen in the fuel have to combine with

oxygen at the combustion temperature in order to release heat. The oxygen is obtained from air, but only 21% of air is oxygen. The remaining nitrogen carries the heat away up the chimney, so too much air is bad. However too little air means that there is not enough oxygen for complete combustion, and particles of unburnt fuel go up the chimney or cause soot on the fire side surface of the boiler.

The air:fuel ratio is set on the controls of the burner, for pressure jet and rotary cup burners and by the pressure of gas on an atmospheric boiler.

While there is a theoretical amount of air required for each type and grade of fuel, in practice some excess air is always required to ensure a good mix of fuel and air in the combustion chamber. The effectiveness of this mix can be measured in the flue leading to the chimney, by sampling the gases for carbon dioxide (CO_2), oxygen (O_2) and carbon monoxide (CO). The table below provides some targets to aim for.

Fuel	Theoretical CO_2 (%)	Target CO_2 (%)	Target O_2 (%)
Coal	**18.6**	**12.0**	**7.3**
Gas	**11.7**	**10.0**	**3.2**
Heavy oil (3,500 sec)	**16.0**	**13.2**	**3.6**
Light oil (35 sec)	**15.4**	**12.6**	**3.8**

Any CO in the flue gases indicates that there is unburnt fuel and if the figure is above 200 ppm then the excess air should be increased.

It should be noted that the above figures are targets. Different boilers and different manufacturers may not be able to achieve these levels; consult the manufacturer of your boiler to find out the optimum figures for your boiler configuration.

Insulating the boiler will minimise losses from the casing (or shell). All modern boilers will have optimum levels of insulation to reduce the standing losses from the boiler. Older boilers may never have had an insulating jacket or it may have been removed at some time for maintenance and not replaced. Remember that the heat lost from the shell of the boiler will be constant regardless of the output of the boiler, as long as the boiler is at its operating temperature. Therefore on larger boilers, where the output of the boiler modulates to follow the load, the standing losses will be a higher proportion of the fuel at low loads. ie if losses are 4% at high fire they may be 8% at mid fire.

Blowdown is when some of the boiler water is removed from the boiler by opening a valve to drain. Hot boiler water is therefore lost. Blowdown should be minimised, consistent with maintaining good water quality within the boiler. The parameter used to measure this water quality is called 'Total Dissolved Solids' (TDS). This figure should be kept as close as possible to the manufacturer's recommended level. Systems are available that can automate the blowdown process. These systems can have continuous bleed and timed bottom blowdown to maintain set TDS levels. If blowdown rates are necessarily high because of TDS then heat recovery equipment may be worthwhile.

Other considerations

Controls

Where there are a number of boilers serving the heat load, energy savings can be achieved by sequencing the boilers so that all the boilers are not firing at the same time for short periods. Ensuring that the heat load is met by the smallest number of boilers will reduce standing losses, provided the remaining boilers are automatically isolated.

Time controls should be set to provide heating only when required. On boilers over about 100kW it is worth

investigating optimum start controls rather than a simple time switch.

Temperature controls should be set to provide the minimum required to satisfy the load. Where the boiler is providing only space heating then a weather compensator will vary the heat output of the boiler with respect to outside air temperatures.

Ancillaries

On larger boiler plant, the fitting of flue gas dampers to isolate offline boilers from the chimney will prevent cooling air being drawn through the boiler.

Large boilers with fixed speed combustion air fans can benefit from the use of variable speed drives fitted to the fan motor in place of damper controls.

In some instances it is possible to fit a heat exchanger (called an economiser) into the flue of the boiler, before the chimney, to recover some of the energy in the hot flue gases. This is normally used to preheat the makeup water to a steam raising plant or reheat the return water to hot water boilers. When running on natural gas the economiser can achieve condensing conditions in some instances.

On steam plant, once the energy in the steam has been used, what is left is condensate. This is water that is at a temperature that is very close to boiling point and that has already been through the water treatment plant. It therefore has a very high value. All condensate should be returned to the boilerhouse for reuse in the system unless it has been contaminated during use. In this case heat recovery should be considered.

On any system, leakage is a major energy waste and should be eliminated by regular inspections and repair.

Insulation on pipework, valves, flanges and other fittings will minimise losses outside the boilerhouse.

Action plan

Suggest to your colleagues and supervisor that the boiler system efficiency should be reviewed.

Action checklist

- **Find the cost of the fuel used in the boilerhouse.**
- **Get the combustion efficiency of the boilers checked.**
- **Compare the efficiency figure with the manufacturer's expected figure.**
- **Record the flue gas temperature over a few months. A rising temperature indicates boiler fouling. A rise of 17°C represents a drop in efficiency of 1%.**
- **Check that the boiler is adequately insulated.**
- **Check that controls are set appropriately.**
- **Check for leaks on the system.**
- **Ensure that maintenance is carried out effectively.**
- **For a steam system ensure that all condensate is returned to the hot well.**
- **Ensure all ancillary equipment and pipework is adequately insulated.**
- **Contact the Environment and Energy Helpline for more technical advice, publications and information.**

Finding out more

Environment and Energy Helpline 0800 585794

Call us for help on any energy or environment-related question, and to order the free publications below:

- ***Energy efficient operation of industrial boiler plant*** **(Good Practice Guide 30)**
- ***Energy efficient heat distribution*** **(Good Practice Guide 197)**
- ***Improving boiler energy efficiency through water treatment*** **(Good Practice Guide 221)**
- ***Steam generation costs*** **(Energy Consumption Guide 66)**
- ***Steam distribution costs*** **(Energy Consumption Guide 67)**
- ***Economic use of oil-fired boiler plant*** **(Fuel Efficiency Booklet 14)**
- ***Economic use of gas-fired boiler plant*** **(Fuel Efficiency Booklet 15)**
- ***Economic use of coal-fired boiler plant*** **(Fuel Efficiency Booklet 16)**

For practical advice on how to reduce your organisation's energy costs, visit our web site: **http://www.energy-efficiency.gov.uk**

Other sources of information

The Combustion Engineering Association

1a Clarke Street
Ely Bridge
Cardiff
CF5 5AL
tel 02920 400 670
fax 02920 400 672
web site: www.cea.org.uk

The CEA publish *A Guide to Steam Plant Operation*, a 40-page guide to the energy efficient and safe use of steam.

Other guides in the series:

- *Saving energy and reducing waste*
- *Compressed air*
- *Maintenance*

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